Pavement Materials & Design

3.2_Aggregates Characterization tests _ Other Tests

Dr. Hamza Alkuime

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Importance of Laboratory Testing and Specifications in Civil Engineering

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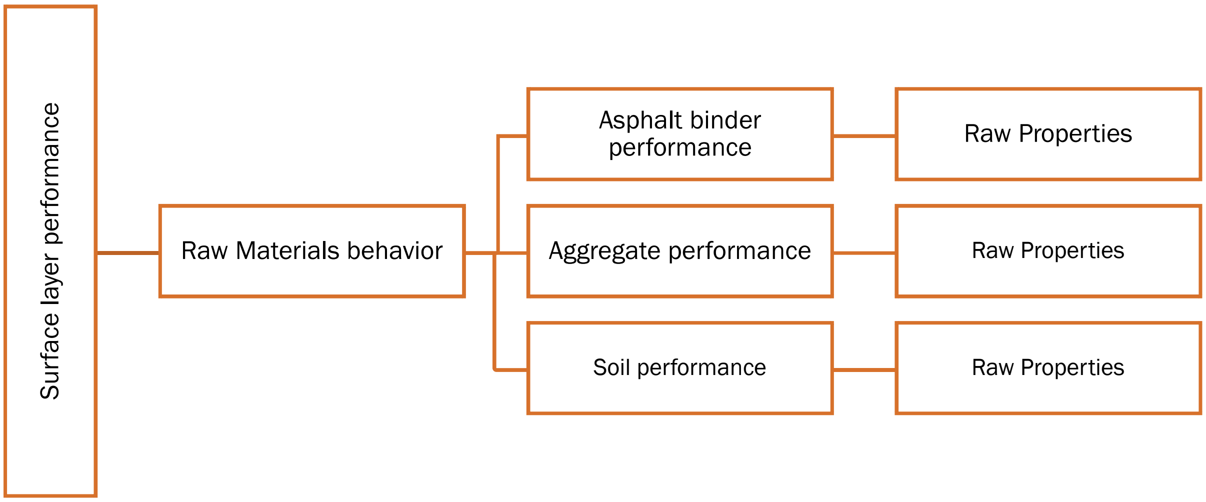

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- A level of pavement Performance is required
- Prevent Rutting

- This performance is affected by Soil Plastic behavior

- It requires a soil with low plastic behavior

- Insite soil is only available

- Atterberg limits tests is used to examin this property of soil

- Specification are used to ensure that the required property has been controlled to achieve the desire performance

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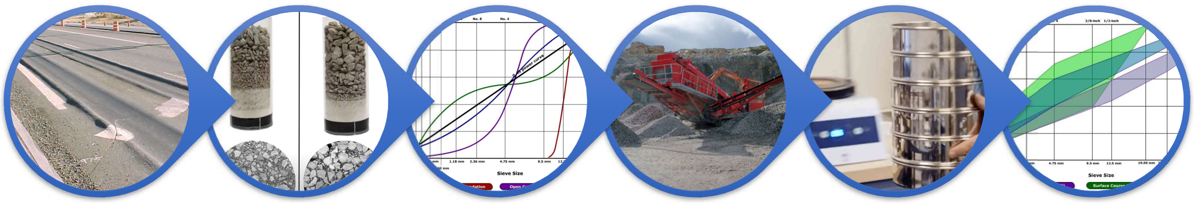

- A level of pavement Performance is required
- This performance is affected by the **grading** property of the aggregate
- It requires a specific grading
- (Well Graded)
- Sources are stockpiles with different grading (Property)
- Sieve Analysis test used to examin this property of aggregate (Properties)
- Specifications are used to ensure that the required property has been controlled to achieve the desire performance

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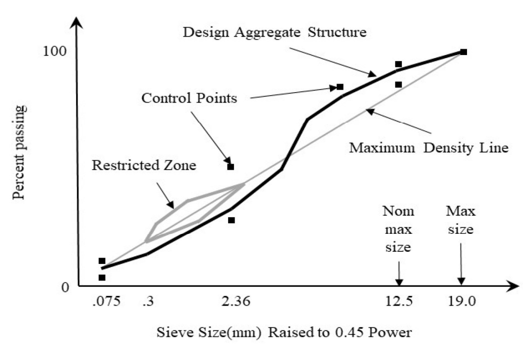
From Blending Phase

We control the Grading Property of selected aggregates stokpiles



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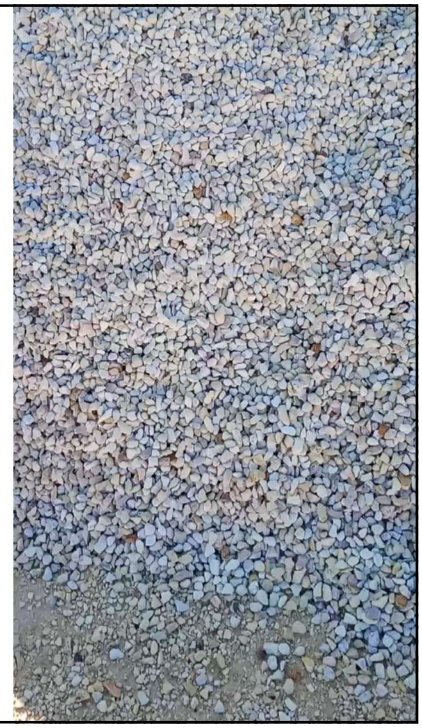
Other Properties



- However, there are other properties that need to be controlled.
- Otherwise, We will not have the desired level of performance

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Other assessment tests

Aggregate Identification		Coarse Agg.	Medium Agg.	Fine Agg. 1	Fine Agg. 2	Cold Bins	
		(Basalt)			(L.S)		
		حصية (بازلت)	عدسية (بازلت)	ناعمة 1 (بازلت)	ناعمة 2 (جيري)		
Test Name		Test Result				Test Standard	JAS
- Sieve Analysis: -		% Passing by Weight					
Sieve Number (Size, mm):	1" (25)	100	100	100	100	AASHTO T 27-18, AASHTO T 11-05 (2018)	☆
	3/4" (19)	100	100	100	100		
	1/2" (12.5)	25	94	100	100		
	3/8" (9.5)	3	66	100	100		
	No. 4 (4.75)	1	4	98	99		
	No. 8 (2.36)	1	1	68	69		
	No. 20 (0.850)	1	1	37	45		
	No. 50 (0.300)	1	1	21	30		
	No. 80 (0.180)	1	1	17	23		
	No. 200 (0.075)	0.4	0.5	11	20		
- Specific Gravity (SG):	Bulk SG. (Oven Dry)	2.743	2.732	2.859	2.517	AASHTO T 84-17, AASHTO T 85-18	☆
	Bulk SG. (SSD)	2.791	2.783	2.917	2.593		
	Apparent SG.	2.882	2.880	3.037	2.724		
- Water Absorption, %		1.8	1.9	2.1	3.0		
- Atterberg Limits	Liquid Limit	---		--	18	AASHTO T 89-17 (Method A), AASHTO T 90-16	☆
	Plastic Limit	---		--	16		
	Plasticity Index	---		N.P	2		
- Flakiness Index		19	22	--	--	BS 812: Part 105.1, 1989	☆
- Elongation Index		21	24	--	--	BS 812: Part 105.2, 1990	☆
- Abrasion Loss (500 cycles), %		23	24	--	--	AASHTO T 96-02 (2019)	☆
- Ratio of wear loss (100/500)		0.21	0.23	--	--		
- Clay Lumps, %		0.10	0.16	0.28	0.64	AASHTO T 112-00 (2017)	☆
- Gypsum Content (SO_3), %		0.021			0.044	EN 1744-1: 2012	☆
- Chloride Content (Cl), %		0.006			0.003	EN 1744-1: 2012	☆
- Soundness Loss (Na_2SO_4), %		1.09	1.53	---	---	AASHTO T 104-99 (2016)	☆
- Fractured Faces (at least two), %		100	100	---	---	AASHTO T 335-09 (2018)	☆
- Chert & Flint Content, %		Nil	Nil	---	---	IHM/EAS 003 - 2019 (*)	☆
- Vesicular Particles, %		4	3	---	---	By Inspection	--
- Polished Stone Value, PSV		65		---	---	BS 812, BS EN 1097-8 (2000)	--

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Test Name	Property Measured
Sieve Analysis	Particle Size Distribution
Atterberg Limits	Plasticity and Workability
Clay Lumps	Clay Content in Aggregate
Water Absorption	Water Uptake of Aggregates (%)
Specific Gravity	Density of Aggregate Particles
Flakiness Index	Particle Shape - Flatness
Elongation Index	Particle Shape - Elongation
Abrasion Loss	Resistance to Wear and Degradation
Ratio of Wear Loss	Aggregate Wear Loss (%)
Gypsum Content (SO_3)	Sulfate Content
Chloride Content (Cl)	Chloride Ions
Soundness Loss	Resistance to Weathering (Freeze-Thaw)
Fractured Faces	Percentage of Fractured (Angular) Surfaces
Chert & Flint Content	Presence of Chert and Flint
Vesicular Particles	Quantity of Porous Particles
Polished Stone Value (PSV)	Skid Resistance after Polishing

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Assessment of cleanness of fine aggregates and fines

Clay Lumps and Friable Particles in Aggregates

(AASHTO T 112)

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Clay Lumps

Test Concept

- **Test Purpose:** Identifies and quantifies clay lumps and friable particles in aggregates, which are unwanted weak materials.
- **Significance:** These materials can break down under typical pavement stresses, affecting the durability and performance of the aggregate.
- The test involves **soaking, kneading, and visual inspection** of the aggregate to identify and quantify the amount of material that breaks down.

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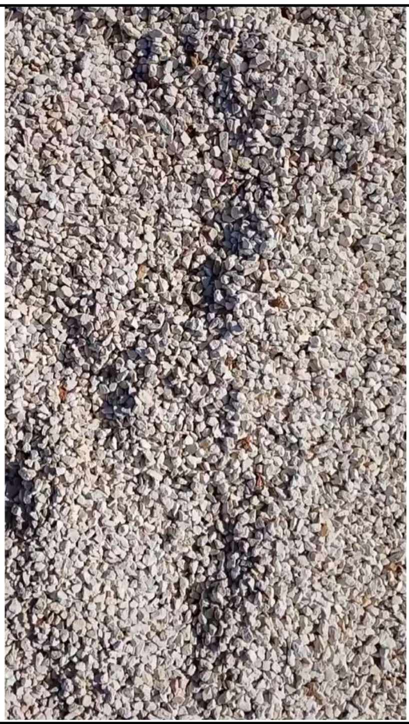
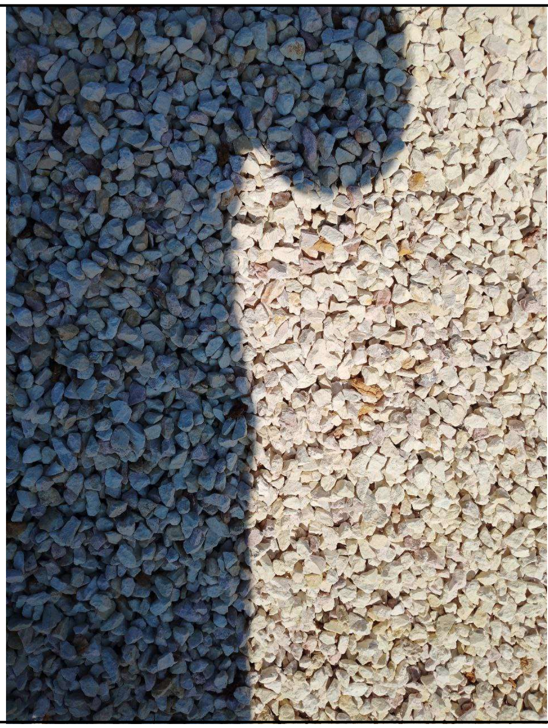
Clay Lumps





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Clay Lumps

1. **Sample Preparation:**
   - *Obtain a representative aggregate sample (typically 500 grams) from the stockpile or batch.*
   - *Dry the sample thoroughly to a constant weight.*
2. **Initial Weight Measurement:**
   - *Record the dry weight of the sample before starting the test.*
3. **Soaking and Disintegration:**
   - *Immerse the sample in water for a specified duration (e.g., 24 hours) to soften any clay lumps or friable particles.*
   - *After soaking, rub and break down any softened particles by hand under gentle pressure to disintegrate clay lumps.*
4. **Screening:**
   - *Wash the sample over a designated sieve size (usually 1.70 mm or No. 12 sieve) to separate disintegrated clay lumps from the remaining aggregate.*
   - *Retain the material on the sieve for further measurement.*
5. **Final Drying and Weighing:**
   - *Dry the material retained on the sieve to a constant weight and record the weight.*

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Clay Lumps

Calculations

- **Calculation of Clay Lumps Content:**
  - ***Formula:***

$$\text{Percentage of Clay Lumps} = \left(\frac{\text{Original Weight - Final Weight after Washing}}{\text{Original Weight}} \right) \times 100$$

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Clay Lumps

Interpretation of Testing Results on Layer Performance

Excessive clay lumps and friable particles can:

- **Reduce stability:**
  - *Weak particles compromise the load-bearing capacity of pavement layers, making them more susceptible to rutting and deformation.*
- **Increase permeability:**
  - *These particles can create pathways for water to infiltrate the pavement, leading to moisture damage and decreased durability.*
- **Reduce bonding:**
  - *Clay lumps can interfere with the adhesion between the aggregate and binder, resulting in poor aggregate coating and increased potential for stripping.*

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Assessment of cleanness of fine aggregates and fines

Sand Equivalent test

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Sand Equivalent test

Test Concept

- **Purpose:**
  - *Measures the cleanliness of fine aggregates, especially for asphalt pavements.*
- **Significance:**
  - *High clay and fines content can weaken the bond between asphalt binder and aggregates, impacting pavement durability and performance.*

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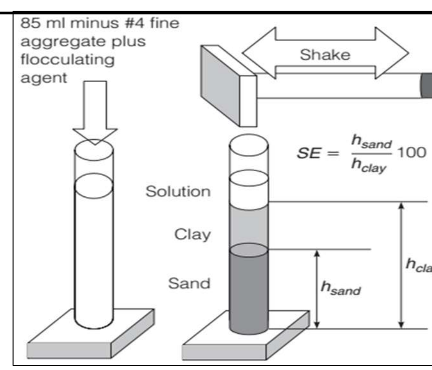
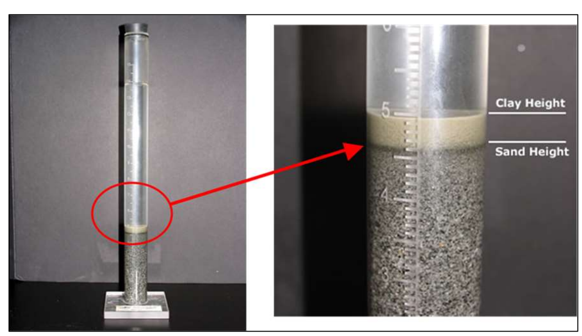
Sand equivalent test

Test Procedures

- **Sample Preparation:**
  - *Obtain a representative sample of fine aggregate (typically passing a 4.75 mm sieve),*
- **Preparation of Solution and Sample Mixing:**
  - *Fill a graduated cylinder with a standard calcium chloride solution.*
  - *Add the aggregate sample and agitate the mixture to suspend any clay particles.*
- **Sedimentation Phase:**
  - *Allow the sample to settle for a prescribed period, during which sand particles settle first and clay remains suspended.*
- **Measurement:**
  - *After sedimentation, measure the height of both the sand and clay layers within the cylinder.*





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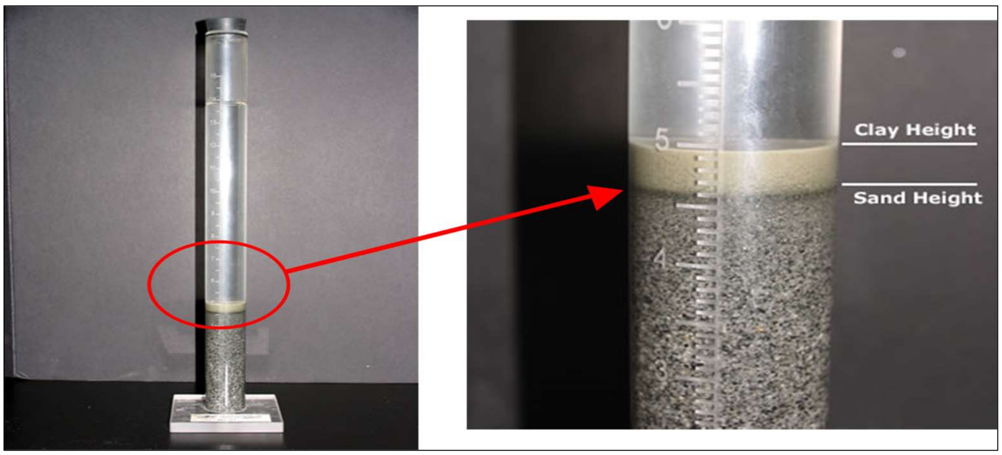
Sand equivalent test

- **Sand Equivalent Calculation:**

$$\text{Sand Equivalent (SE)} = \left(\frac{\text{Height of Sand Layer}}{\text{Height of Clay Layer}}\right) \times 100$$



Sand Equivalent test

Interpretation of Testing Results on Layer Performance

- **Higher SE Values:**
- **Indicate:** Cleaner aggregates with less clay and fine material content.
- **Effects:**
  - *Stronger bond between asphalt binder and aggregate.*
  - *Reduced risk of stripping and moisture damage.*
  - *Enhanced pavement durability and resistance to rutting and raveling*

1. Los Angeles (LA) Abrasion test

Los Angeles (LA) abrasion test

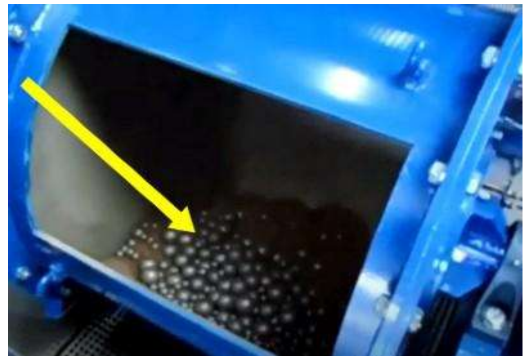
Test Concept

- **Purpose:**
  - Evaluates the resistance of coarse aggregate to abrasion and impact.
- **Significance :**
  - Predicts the potential for aggregate particles to break down under traffic loads, which can lead to pavement deterioration.

Los Angeles (LA) abrasion test

Procedures

- **Step 1: Aggregate Preparation**
  - Select and dry the aggregate sample.
  - Weigh a specific mass of aggregate based on standard requirements.
- **Step 2: Loading the Drum**
  - Place the aggregate and steel balls into the rotating drum
- **Step 3: Testing**
  - Set the drum to rotate for **500 cycles** at a standard speed.
- **Step 4: Post-Test Sieving**
  - After 500 cycles, sieve the aggregate sample.
  - Use a **1.7 mm sieve** to separate the fine material



Los Angeles (LA) abrasion test

Calculation of Abrasion Loss

- Calculation

$$\text{Abrasion Loss (\%)} = \frac{\text{Initial Weight of Sample} - \text{Final Weight of Sample after 500 cycles}}{\text{Initial Weight of Sample}} \times 100$$

Where:

- **Initial Weight of Sample** = The weight of the aggregate sample before the test.
- **Final Weight of Sample after 500 cycles** = The weight of the aggregate sample after undergoing 500 cycles of abrasion.

$$\text{Ratio of Wear Loss} = \frac{\text{Weight loss after 500 cycles}}{\text{Weight loss after 100 cycles}}$$

Los Angeles (LA) abrasion test

Test Results Interpretation - Effects on Pavement Layer Properties

- **Lower Abrasion Values:**
  - Indicate tougher, more durable aggregates that are less susceptible to fragmentation and degradation under traffic loading.
  - This translates to improved performance in terms of rutting resistance, skid resistance, and resistance to surface distresses such as raveling and potholes.

Particle shape tests of coarse aggregates

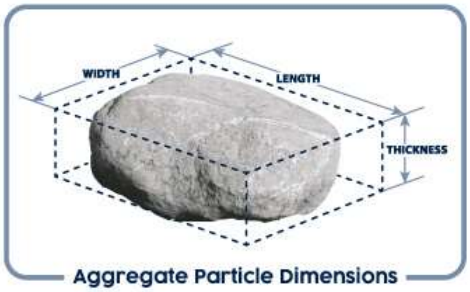
Flakiness Index (BS 812: Part 105.1, 1989)

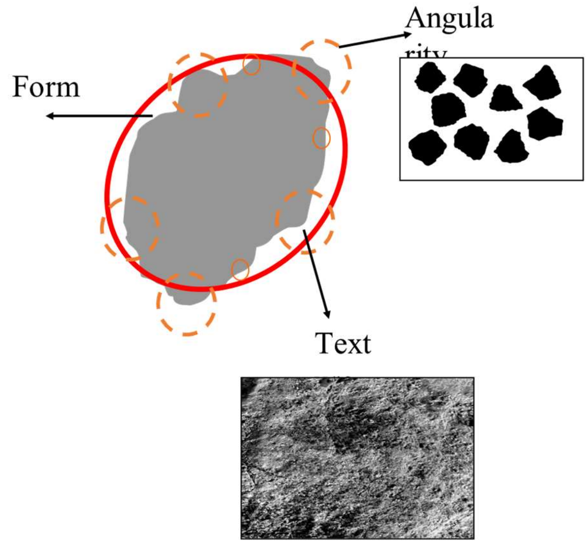
And

Elongation Index (BS 812)

Aggregate Particle Shape

- Particle shape refers to the three-dimensional geometric form of individual aggregate particles.





Aggregate Particle Shape

Common shape descriptors include:

- **Angular:**
  - Particles with sharp edges and corners, typically resulting from crushing.
- **Rounded:**
  - Particles with smooth, curved surfaces, often found in natural gravel deposits.
- **Cubical:**
  - Particles with a roughly equal length, width, and thickness, approaching a cube-like form.
- **Flat and Elongated:**
  - Particles with one dimension significantly larger than the other two, resembling a flattened or elongated shape.

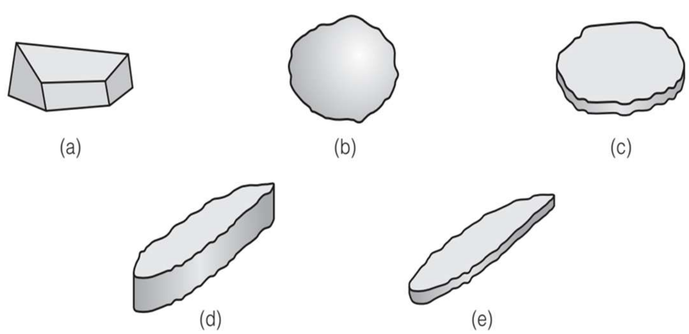


FIGURE 5.3 Particle shapes: (a) angular, (b) rounded, (c) flaky, (d) elongated, and (e) flaky and elongated.

Flakiness Index and Elongation index

Definitions of Main Parameters

- **Flakiness Index:**
  - **Definition:** The percentage by weight of flat particles in the sample.
  - **Purpose**: Measures the proportion of flat particles in a sample of coarse aggregate.
- **Elongation Index:**
  - **Definition:** The percentage by weight of elongated particles in the sample.
  - **Purpose**: Measures the proportion of elongated particles in a sample of coarse aggregate..
- **Significance:**
  - Flat and elongated particles can weaken the aggregate structure and reduce its resistance to crushing and abrasion.

Flakiness Index and Elongation index

- **Flakiness Index (%) =**
  - (Weight of flaky particles / Total weight of sample) x 100
  - (Number of flaky particles / Total number of particles) x 100
- **Elongation Index (%) =**
  - (Weight of elongated particles / Total weight of sample) x 100
  - (Number of elongated particles / Total number of particles) x 100

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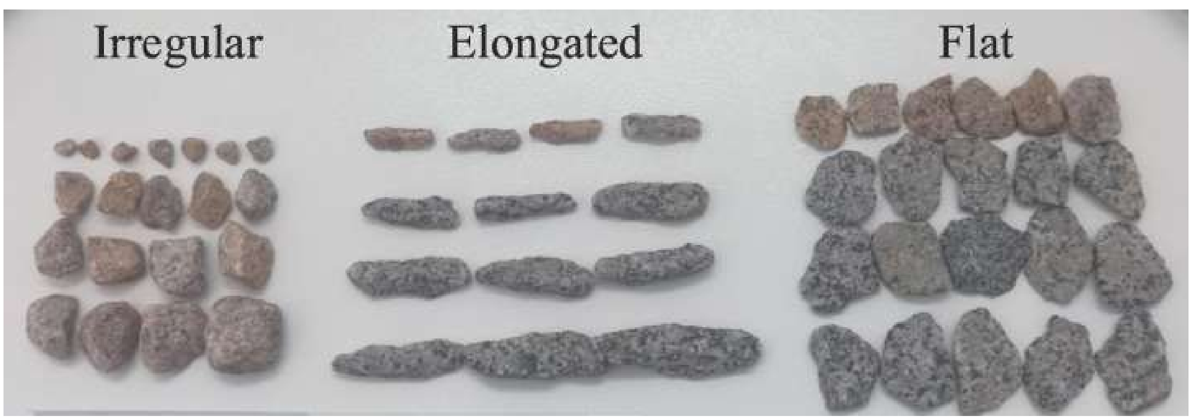

20 Particle   12 Particle   21 Particle

There are 20 + 12 + 21 = 53 total particles.

Flakiness Index = (21 / 53) x 100 ≈ 39.62%

Elongation Index = (12 / 53) x 100 ≈ 22.64%

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Flakiness Index and Elongation index

Interpretation of Testing Results on Layer Performance

- Higher **Flakiness Index and elongation index** **(More Flat/Elongated Particles)**

Negative effects:

- **Reduced Interlocking and Stability:** Flat particles hinder proper interlocking, leading to decreased shear strength and stability.
- **Increased Void Content:** Irregular packing due to shape variations results in higher void content, affecting compaction and permeability.
- **Susceptibility to Breakage:** Flaky particles are more vulnerable to crushing under traffic loads, leading to degradation and reduced durability.
- **Workability Issues:** High flakiness can make compaction more challenging, potentially leading to inconsistencies in layer density and performance

- Note: **Lower Flakiness Index = More Cubical/Angular Particles**

Particle shape tests of coarse aggregates

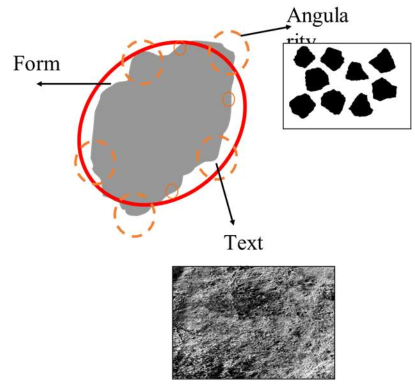
Crushed and broken surfaces test

Fractured Faces test

Percentage of Fractured Particles in Coarse Aggregate

Test Concept

- **Purpose:**
  - *Determines the percentage of fractured (angular) particles in coarse aggregate.*
  - *Evaluates the **angularity** of coarse aggregate particles.*
- **Significance:**
  - *Fractured particles improve interlocking, which enhances the stability, strength, and load-bearing capacity of the aggregate mix.*



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Aggregate Particle Shape

- **Angular:**
  - *Particles with sharp edges and corners, typically resulting from crushing.*
- **Rounded:**
  - *Particles with smooth, curved surfaces, often found in natural gravel deposits.*

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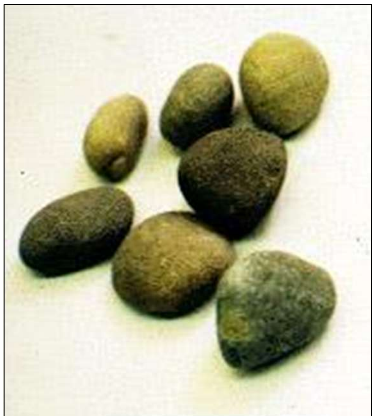
Percentage of Fractured Particles in Coarse Aggregate

Aggregate with many fractured faces.

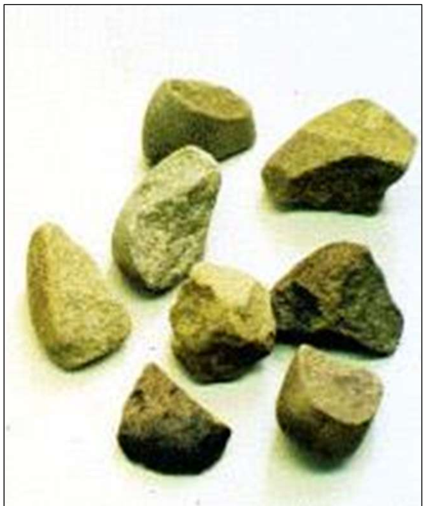
Percentage of Fractured Particles in Coarse Aggregate

Definition of Main Parameter

- **Coarse Aggregate Fractured Faces (CAFF):** This term is used to describe the test results.
- **CAFF (%) =**
  - **(Number of Particles with Fractured Faces / Total Number of Particles) x 100**
- The calculation is performed separately for
  - Particles with at least one fractured face and
  - Particles with at least two fractured faces.



0% Crushed

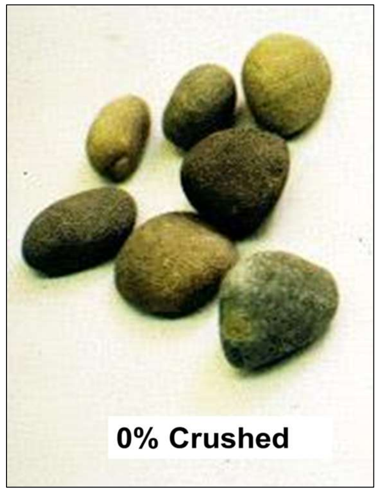


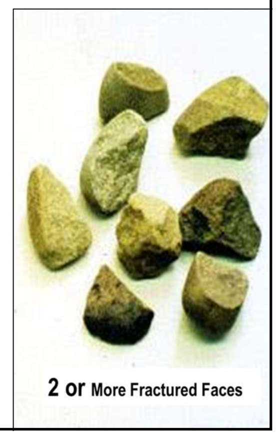
2 or More Fractured Faces

Percentage of Fractured Particles in Coarse Aggregate

Definition of Main Parameter

- **Total number of particles:** 15
- Number of particles with 2 or more fractured faces = 8
- CAFF = (8 / 15) x 100 ≈ 53.33%





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Percentage of Fractured Particles in Coarse Aggregate

Interpretation of Testing Results on Layer Performance

Higher CAFF Values (More Fractured Faces)

Positive Effects:

- **Enhanced Interlocking and Stability:**
  - More angular particles lead to increased friction and interlocking, resulting in greater shear strength and resistance to rutting.
- **Improved Load Transfer**:
  - A well-interlocked aggregate structure efficiently distributes stresses under traffic loads, contributing to a more durable pavement.

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Assessment of cleanness of fine aggregates and fines

Chert & Flint Content

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Understanding the Issue:

What is Chert?

- **Composition**:
  - *Chert is primarily composed of microcrystalline or cryptocrystalline quartz (silica, SiO_2).*
  - *Various colors, from white and gray to red and green.*
- **Properties**:
  - *Chert is very hard and brittle, making it resistant to abrasion but prone to fracturing under freeze-thaw conditions.*
- **Occurrence**:
  - *Chert is commonly found in limestone and dolomite rock formations.*

Chert: A specimen of gray chert from near Joplin, Missouri. The specimen is opaque with a coarse texture, with numerous voids and fractures. It might be used for tool-making, but knapping performance would be poor. Specimen is approximately four inches across.

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Chert & Flint Content

What is Flint?

- **Composition**:
  - *Flint is a type of chert with a similar silica-based composition, but it tends to be darker, often black or dark gray, due to the presence of organic material.*
- **Properties**:
  - *Like chert, flint is hard and brittle.*
  - *It also has a high resistance to abrasion but is susceptible to fractures under freeze-thaw cycles.*
- **Occurrence**:
  - *Flint is typically found in chalk or limestone deposits and is often associated with marine sedimentary environments.*

Flint: A specimen of brown, translucent flint from Minas Gerais, Brazil. This specimen has a fine-grained, uniform texture that should perform well in manufacturing tools. Specimen is approximately four inches across.

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Chert & Flint Content

Test idea

- Purpose:
  - *Measures the percentage of chert and flint particles within aggregate samples.*

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Chert & Flint Content

Test Procedures

1. **Sample Collection and Preparation:**
   - *Obtain a representative aggregate sample, ensuring it is thoroughly dried.*
   - *Typically, the sample should be sieved to obtain a specific particle size range (e.g., 4.75 mm to 19 mm) for testing.*
2. **Visual Inspection and Sorting:**
   - *Visually inspect the aggregate particles for chert and flint characteristics, such as color, texture, and hardness.*
   - *Separate and count particles that match the characteristics of chert and flint.*
3. **Weight Measurement:**
   - *Weigh both the original aggregate sample and the isolated chert and flint particles to obtain precise mass values.*
4. **Recording Observations:**
   - *Record the number and weight of chert and flint particles, noting any characteristics of the aggregate sample that may impact the results.*

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Chert & Flint Content

Calculations + Acceptable Specifications

- **Calculation of Chert & Flint Content:**
  - ***Formula:***

Chert & Flint Content (%) =

$$(Weight of Chert and Flint Particles / Total Weight of Aggregate Sample) x 100$$

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Chert & Flint Content

Interpretation of Testing Results on Layer Performance

Higher Chert & Flint Content:

- **Potential Negative Effects:**
  - ***Polishing:*** *Chert and flint are susceptible to polishing under traffic, reducing skid resistance and potentially compromising safety.*
  - ***Aggregate Loss:*** *These hard rocks may break down into sharp fragments, contributing to aggregate loss and surface deterioration.*

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Durability & Resistance to Weathering

Soundness Test

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Soundness Test

- **Purpose:**
  - *Measures the resistance of aggregates to disintegration when exposed to repeated cycles of **wetting and drying** in a saturated solution of **sodium sulfate (Na_2SO_4)**.*
- **Significance:**
  - **Simulating Field Conditions:** The test subjects aggregates to **accelerated weathering conditions** in the laboratory, simulating the natural processes that can lead to aggregate breakdown over time.

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Soundness Test

Test Procedure (AASHTO T 104-99):

- **Prepare aggregate sample** and dry it to a constant weight.
- Immerse the sample in a **sodium sulfate (Na_2SO_4)** solution and allow it to soak for a specified period.
- **Dry the sample** and repeat the process for a specified number of cycles (usually **5 cycles**).
- After the final drying, **sieve** the aggregates and weigh the amount of material lost.

Before

After

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Soundness Test

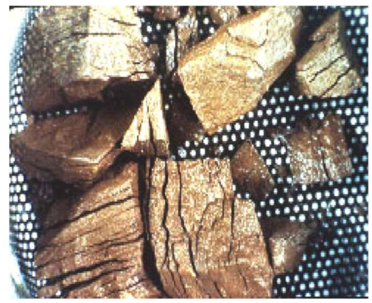
Calculations

- Calculate the **Soundness Loss** using the formula:

$$\text{Soundness Loss (\%)} = \frac{\text{Weight of material lost}}{\text{Initial weight of sample}} \times 100$$

Before

After



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Soundness Test

Interpretation of Testing Results on Layer Performanc

- **Higher Values:**
- **Indicate:**
  - Higher mass loss, indicating greater susceptibility of the aggregate to weathering and disintegration.
- **Effects:**
  - *Reduced pavement layer strength and durability.*
  - *Increased potential for potholes, raveling, and other pavement distresses.*

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Vesicular Particles

Vesicular aggregate Particles

Definition

- **Vesicular aggregates** are types of aggregate materials that contain **vesicles**,
- **Vesicles** are small, rounded cavities or air pockets formed as a result of volcanic activity or gas entrapment in the rock.
- Some common examples of vesicular rocks include **basalt**.
- Purpose
  - *This test focuses on identifying and quantifying **vesicular particles** within aggregate samples.*

Vesicular Particles

Test Procedures

- **Visual Inspection:**
  - ***Direct Observation:*** *Visually examine the aggregate particles to identify those with visible voids or cavities.*
  - ***Magnifying Glass:*** *Use a magnifying glass to examine the particles in more detail.*
- **Density Tests:**
  - ***Bulk Density Test:*** *Determine the bulk density of the aggregate, which can be affected by the presence of vesicular particles.*
  - ***Specific Gravity Test:*** *Measure the specific gravity of the aggregate to assess the degree of porosity and the potential for water absorption.*

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Vesicular Particles

Interpretation of Testing Results on Layer Performance

- **Higher Values:**
- **Indicate:** A greater proportion of vesicular particles in the aggregate.
- **Effects:**
  - *Potential for reduced strength and durability of the aggregate.*
  - *Increased susceptibility to crushing and **degradation** under load.*
  - *May require adjustments in mixture design to compensate for weaker particles.*

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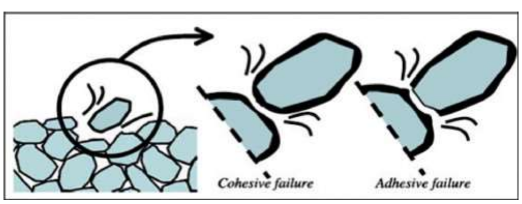
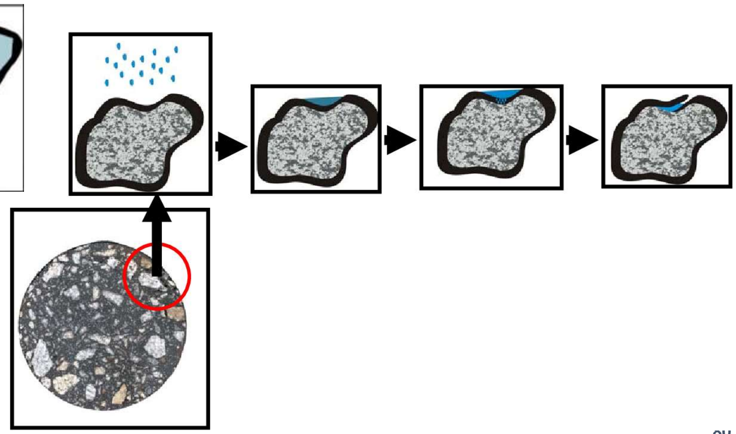
Stripping (Moisture Damage) Assessment tests

Static and Dynamic Stripping Tests

What is stripping

- **Stripping** in an asphalt mixture is the separation or loss of the bond between the asphalt binder and the aggregate particles, primarily due to the presence of moisture.





What is stripping

- This phenomenon leads to a weakening of the pavement structure and can cause several types of damage, including potholes,.

Aggregate Surface Chemistry

- Surface chemistry determines whether aggregates are hydrophobic or hydrophilic,.
- Hydrophobic Agg (Water-hating)
  - *Have a preference for wetting by asphalt as opposed to water.*
  - *Work well in asphalt concrete (show little or no strength reduction)*
  - *Aggregates that are basic, such as limestone and dolomite, have a positive surface charge.*
- Hydrophilic Agg (Water-loving)
  - *Hydrophilic aggregates attract moisture to its surface, which can even displace a previously established asphalt coating*
  - *Acidic aggregates, such as granite and siliceous gravel containing chert and quartzite, is hydrophilic, Have a negative surface charge*

Static and dynamic Stripping Test (AASHTO T182)

- ❑ Purpose:
  - ➢ *Evaluates the susceptibility of asphalt-aggregate mixtures to moisture damage*
- ❑ **Calculations:**
- **Percentage of Stripping:**

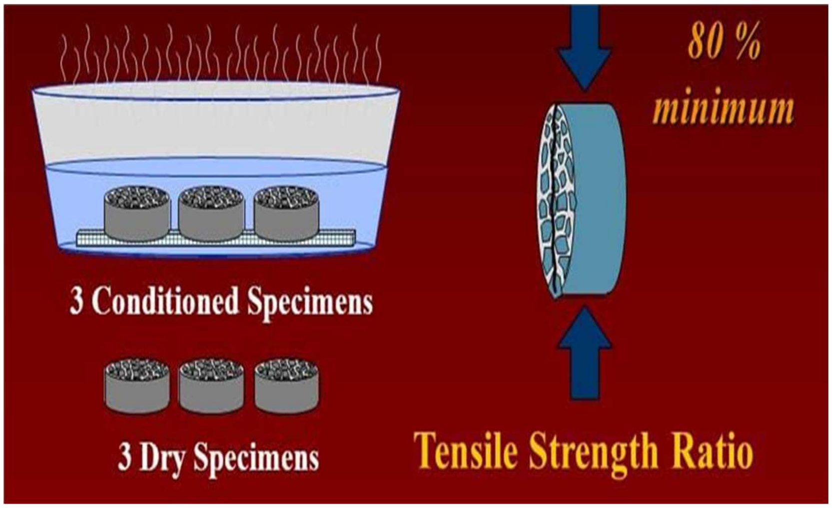
$$\text{Stripping Percentage} = \frac{\text{Area of Aggregate without Bitumen Coating}}{\text{Total Aggregate Surface Area}} \times 100$$

Static Stripping Test (AASHTO T182)

Interpretation of testing results

- ❑ **High Percentage of Stripping:**
  - ➢ *means that a significant portion of the asphalt binder has separated from the aggregate under test conditions, indicating a strong susceptibility to moisture-induced damage.*
  - ➢ ***Poor Moisture Resistance:***
    - ❖ A high stripping percentage suggests that the asphalt-aggregate bond is weak when exposed to water, making the mixture vulnerable to moisture penetration.
    - ❖ This can result in early degradation of the pavement under environmental conditions
  - *Potential for Pavement Failure:*
    - High stripping indicates that the pavement is likely to experience stripping-related distresses such as: potholes, rutting.

Loss of Marshall stability test



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Polished Stone Value (PSV)

BS 812, BS EN 1097-8 (2000)

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Polished Stone Value (PSV)

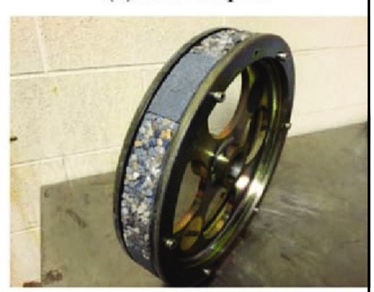
- Purpose
  - ***Skid Resistance****: PSV assesses the aggregate's ability to resist polishing from traffic wear, which is crucial for maintaining road safety by preventing skidding, particularly in wet conditions.*

Polished Stone Value (PSV)

Test procedures

1. **Aggregate Preparation:**
   1. *Select aggregate samples and prepare them by embedding them in molds to form small test specimens.*

(b) Rest coupons



(c) Test coupon placement

Polished Stone Value (PSV)

Test procedures

1. **Polishing Process:**
   1. *Place the samples in a polishing machine that simulates the effect of vehicle tires polishing the aggregates.*
   2. *The machine applies a standard number of revolutions, typically using rubber or pneumatic tires, under controlled conditions.*

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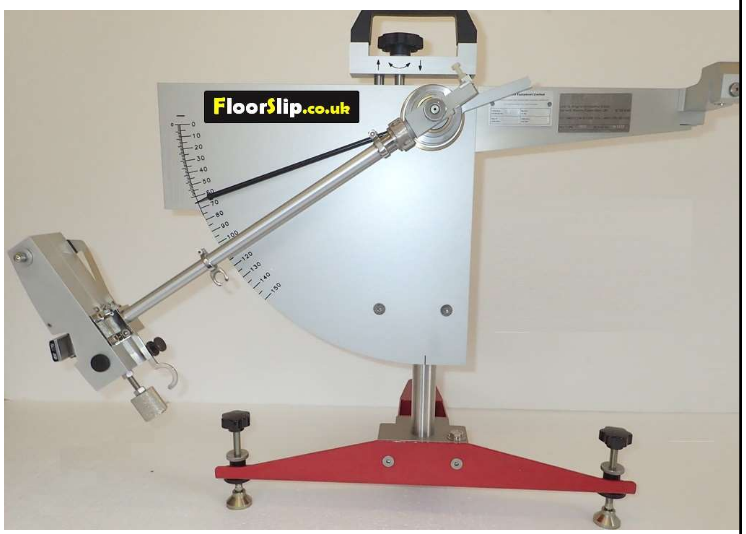
Polished Stone Value (PSV)

Test procedures

- **Skid Resistance Measurement:**
  - *After polishing, measure the skid resistance of the aggregate using a pendulum friction tester.*
  - *The tester is swung over the polished surface, and the friction value (PSV) is recorded.*
- **Higher Values (PSV):**
  - **Indicate:** Higher PSV values mean greater resistance to polishing and better skid resistance.



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Assessment of fine aggregates and fines

Atterberg Limits

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Atterberg Limits

- **Liquid Limit (LL)** – AASHTO T 89-17
  The water content at which soil changes from **plastic** to **liquid**. Determined using a **Casagrande apparatus** or **fall cone**. Soil subjected to repeated blows to measure groove closure.
- **Plastic Limit (PL)** – AASHTO T 90-16
  The water content at which soil can be rolled into threads of **3 mm** diameter without crumbling. Represents the boundary between the **plastic** and **semi-solid** states of soil.
- **Plasticity Index (PI)** – AASHTO T 90-16
  The difference between the Liquid Limit and the Plastic Limit:
- **High PI** values indicate soils with **high plasticity** and **greater shrink-swell potential**.

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Assessment of cleanness of fine aggregates and fines

Gypsum Content (SO_3)
EN 1744

Gypsum Content (SO_3)

- **Definition:** Refers to the sulfur trioxide (SO_3) content in aggregates, often derived from gypsum or sulfate-bearing minerals.

❑ Higher SO_3 Values:

- ➢ A higher SO_3 content suggests an increased risk of stripping and reduced HMA durability.

Assessment of cleanness of fine aggregates and fines

Chloride Content (Cl)

Chloride Content (Cl)

EN 1744-1

- **Chloride Content (Cl):**
  - ***Definition:*** *Refers to the amount of chloride ions (Cl^-) present in aggregates, which may come from natural or contaminant sources.*

❑ **Higher Cl Values:**

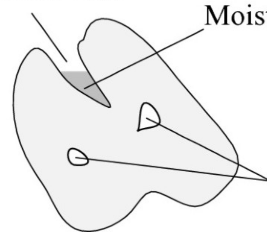
➢ **Indicate:** Higher chloride content signifies a greater risk of corrosion in steel-reinforced concrete pavements.

Pore structure

Pore structure

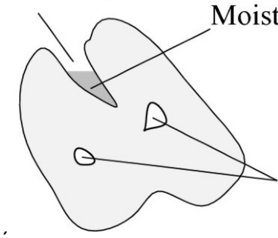
Definition:

- ❑ Pore structure
  - ➢ *Refers to the size, volume, shape, and interconnectedness of the void spaces (pores) within an aggregate particle.*
  - ➢ *This property significantly influences the aggregate's interaction with moisture and binder, impacting its performance in pavement applications.*



Pore structure

Definitions of Main Parameters



- **Pore Size:**
  - The diameter or dimensions of individual pores.
- **Pore Volume:**
  - The total volume of void space within the aggregate pa often expressed as a percentage.
- **Pore Shape:**
  - The geometry of the pores (e.g., spherical, irregular, interconnected).
- **Permeable Pores:**
  - Pores that are interconnected and extend to the surface, allowing fluid flow.
- **Impermeable Pores:**
  - Isolated cavities within the aggregate particle.

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Pore structure

Significance in Construction:

- **Significance for Asphalt Mixtures:**
  - *A large volume of permeable pores is generally undesirable in aggregates used for asphalt mixtures.*
  - *Excessive permeable pore space can lead to:*
    - Increased absorption of asphalt binder, resulting in higher binder demand and increased cost.
    - Difficulty in achieving proper coating of aggregate particles due to water trapped in the pores.
    - Reduced durability as water within the pores can weaken the asphalt-aggregate bond and contribute to stripping.
- **Significance for Base/Subbase Courses:**
  - *Pore structure is critical for base/subbase aggregates as it directly affects their drainage and frost susceptibility.*

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Aggregate Specific Gravity

Will be covered Later !!!

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Can you assess these stockpiles now ?

Aggregate Identification		Coarse Agg.	Medium Agg.	Fine Agg. 1	Fine Agg. 2	Cold Bins	
		(Basalt)			(L.S)		
		[illegible]	[illegible]	[illegible]	[illegible]		
Test Name		Test Result				Test Standard	JAS
- Sieve Analysis: -		% Passing by Weight				AASHTO T 27-18, AASHTO T 11-05 (2018)	☆
Sieve Number (Size, mm):	1" (25)	100	100	100	100		
	3/4" (19)	100	100	100	100		
	1/2" (12.5)	25	94	100	100		
	3/8" (9.5)	3	66	100	100		
	No. 4 (4.75)	1	4	98	99		
	No. 8 (2.36)	1	1	68	69		
	No. 20 (0.850)	1	1	37	45		
	No. 50 (0.300)	1	1	21	30		
	No. 80 (0.180)	1	1	17	23		
	No. 200 (0.075)	0.4	0.5	11	20		
- Specific Gravity (SG):	Bulk SG. (Oven Dry)	2.743	2.732	2.859	2.517	AASHTO T 84-17, AASHTO T 85-18	☆
	Bulk SG. (SSD)	2.791	2.783	2.917	2.593		
	Apparent SG.	2.882	2.880	3.037	2.724		
- Water Absorption, %		1.8	1.9	2.1	3.0		
- Atterberg Limits	Liquid Limit	---		--	18	AASHTO T 89-17 (Method A), AASHTO T 90-16	☆
	Plastic Limit	---		--	16		
	Plasticity Index	---		N.P	2		
- Flakiness Index		19	22	--	--	BS 812: Part 105.1, 1989	☆
- Elongation Index		21	24	--	--	BS 812: Part 105.2, 1990	☆
- Abrasion Loss (500 cycles), %		23	24	--	--	AASHTO T 96-02 (2019)	☆
- Ratio of wear loss (100/500)		0.21	0.23	--	--		
- Clay Lumps, %		0.10	0.16	0.28	0.64	AASHTO T 112-00 (2017)	☆
- Gypsum Content (SO_3), %		0.021			0.044	EN 1744-1: 2012	☆
- Chloride Content (Cl), %		0.006			0.003	EN 1744-1: 2012	☆
- Soundness Loss (Na_2SO_4), %		1.09	1.53	---	---	AASHTO T 104-99 (2016)	☆
- Fractured Faces (at least two), %		100	100	---	---	AASHTO T 335-09 (2018)	☆
- Chert & Flint Content, %		Nil	Nil	---	---	IHM/EAS 003 - 2019 (*)	☆
- Vesicular Particles, %		4	3	---	---	By Inspection	--
- Polished Stone Value, PSV		65		---	---	BS 812, BS EN 1097-8 (2000)	--

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Listing of Available AASHTO and ASTM Test Procedures

AASHTO and ASTM Test Procedures

1. General Testing:

- ❑ AASHTO M-92 (ASTM E 11) Wire Cloth Sieves for Testing Purposes
- ❑ AASHTO M-231 Weights and Balances Used in Testing
- ❑ ASTM Manual of Aggregates and Concrete Testing (found in ASTM Volume 04.02 in the back of the gray pages)
- ❑ AASHTO R 18 Establishing and Implementing a System for Construction Materials Testing Laboratories
- ❑ ASTM D 3666 Evaluation of Inspecting and Testing Agencies for Bituminous Paving Materials
- ❑ ASTM C 1077 Practice for Laboratories Testing Concrete and Concrete Aggregates

AASHTO and ASTM Test Procedures

2. Sampling and Sample Preparation:

- AASHTO T-2 (ASTM D 75) Sampling Aggregates
- AASHTO T-248 (ASTM C 702) Reducing Field Samples of Aggregates to Testing Size
- AASHTO T-87 (ASTM D 421) Dry Preparation of Disturbed Soil and Soil Aggregates Samples for Tests
- AASHTO T-146 Wet Preparation of Disturbed Soil Samples for Tests

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AASHTO and ASTM Test Procedures

3. Particle Size Analysis of Aggregates:

- AASHTO T-27 (ASTM C 136) Sieve Analysis of Fine and Coarse Aggregates
- AASHTO T-11 (ASTM C 117) Amount of Material Finer Than the No. 200 Sieve
- AASHTO T-30 (ASTM D 5444) Mechanical Analysis of Extracted Aggregates
- AASHTO T-88 (ASTM D 422) Particle Size Analysis of Soils
- AASHTO T-37 (ASTM D 546) Sieve Analysis of Mineral Filler

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AASHTO and ASTM Test Procedures

4. Properties of Fines in Aggregates:

- AASHTO T-176 (ASTM D 2419) Sand Equivalent Test for Plastic Fines in Graded Aggregates and Soils
- ASTM D 4318 (Combines AASHTO T-89 and T-90) Liquid Limit, Plastic Limit and Plasticity Index of Soils
- AASHTO T-210 (ASTM D 3744) Aggregates Durability Index
- AASHTO T 330 Standard Method of Test for The Qualitative Detection of Harmful Clays of the Smectite Group in Aggregates Using Methylene Blue

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AASHTO and ASTM Test Procedures

5. Tests to Evaluate General Quality of Aggregates (unconfined or in concrete):

- AASHTO T-104 (ASTM C 88) Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
- AASHTO T-103 Soundness of Aggregates by Freezing and Thawing
- ASTM D 4792 Potential Expansion of Aggregates from Hydration Reactions
- AASHTO T-161 (ASTM C 666) Resistance of Concrete to Rapid Freezing and Thawing
- AASHTO T-96 (ASTM C 131 or C 535) Resistance to Abrasion (Degradation by Abrasion and Impact) of Small or Large Size Coarse Aggregates by Use of the Los Angeles Machine
- ASTM D 6928 (AASHTO T 327) Resistance of Coarse Aggregates to Degradation by Abrasion in the Micro-Deval Apparatus
- ASTM D 7428 Standard Test Method for Resistance of Fine Aggregates to Degradation by Abrasion in the Micro-Deval Apparatus
- ASTM D 4791 Flat or Elongated Particles in Coarse Aggregates

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AASHTO and ASTM Test Procedures

6. Deleterious Materials in Aggregates:

- AASHTO T-21 (ASTM C 40) Organic Impurities in Sands for Concrete
- AASHTO T-71 (ASTM C 87) Effect of Organic Impurities in Fine Aggregates on Strength of Mortar
- AASHTO T-112 (ASTM C 142) Clay Lumps and Friable Particles in Aggregates
- AASHTO T-113 (ASTM C 123) Lightweight Pieces in Aggregates
- ASTM C 294 Nomenclature of Constituents of Natural Mineral Aggregates
- ASTM C 295 Practice for Petrographic Examination of Aggregates for Concrete

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AASHTO and ASTM Test Procedures

7. Test to Evaluate Potential Alkali-Aggregates Reactivity

- ASTM C 227 Alkali Reactivity Potential of Cement-Aggregates Combinations
- ASTM C 289 Potential Reactivity of Aggregates (chemical method)
- ASTM C 586 Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregates (rock cylinder method)
- ASTM C 441 Mineral Admixture Effectiveness in Preventing Excessive Expansion Due to Alkali Aggregates Reaction
- ASTM C 1260 Potential Alkali Reactivity in Aggregates (Mortar Bar Method)
- ASTM C 1293 Determination of Length Change of Concrete Due to Alkali-Silica Reaction
- ASTM C 1105 Length Change of Concrete Due to Alkali-Carbonate Reaction
- ASTM C 1567 Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregates

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AASHTO and ASTM Test Procedures

8. Testing Aggregates in Bituminous Applications:

- AASHTO T-165 (ASTM D 1075) Effect of Water on Cohesion of Compacted Bituminous Mixtures
- AASHTO T-182 Coating and Stripping of Bitumen-Aggregates Mixtures
- AASHTO T-195 (ASTM D 2489) Determining Degree of Particle Coating of Bituminous Aggregates Mixtures
- AASHTO T-283 (ASTM D 4867) Resistance of Compacted Bituminous Mixture to Moisture Induced Damage
- ASTM D 4469 Calculating Percent Absorption by the Aggregates in an Asphalt Pavement Mixture
- ASTM D 6927 Resistance to Plastic Flow-Marshall Apparatus
- ASTM D 1560 Deformation and Cohesion-Hveem Apparatus

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AASHTO and ASTM Test Procedures

9. Aggregates Base Moisture-Density-Permeability Relationships:

- AASHTO T-99 (ASTM D 698) Moisture-Density Relationship Using a 5.5 Pound Rammer and a 12 Inch Drop
- AASHTO T-180 (ASTM D 1557) Moisture-Density Relationship Using a 10 Pound Rammer and an 18 Inch Drop
- AASHTO T-215 (ASTM D 2434) Permeability of Granular Soils (Constant Head)
- AASHTO T-224 (ASTM D 4718) Correction for Coarse Particles in Soil Compaction Tests
- ASTM D 2922 Density of Soil and Soil Aggregates In-Place by Nuclear Methods (shallow depth, both backscatter and direct transmission methods)
- ASTM D 3017 Moisture Content of Soil and Soil Aggregates In Place by Nuclear Methods (shallow depth, back-scatter method only)
- ASTM D 4253 Index Density of Soils Using a Vibratory Table (applicable to cohesionless, free-draining soils or soil aggregates)
- ASTM D 4254 Minimum Index Density and Unit Weight of Soils
- ASTM D 6938 (AASHTO T 310) Density and Water Content of Soil and Soil Aggregates by Nuclear Method (Shallow Depth)
- AASHTO T-191 (ASTM D 1556) Density of Soil In-Place by the Sand Cone Method
- ASTM D 2167 Density of Soil In-Place by the Rubber Balloon Method

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AASHTO and ASTM Test Procedures

10. Strength Parameters of Aggregates Base:

- AASHTO T-190 (ASTM D 2844) Resistance R-Value and Expansion Pressure of Compacted Soils
- AASHTO T-193 (ASTM D 1883) The California Bearing Ratio
- AASHTO T 296 (ASTM D 2850) Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils
- AASHTO T-212 (ASTM D 3397) Triaxial Classification of Base Materials, Soils and Soil Mixtures (Texas method, static loading, discontinued as a standard 1989)
- AASHTO T 236 (ASTM D 3080) Direct Shear of Soils Under Consolidated-Undrained Conditions
- AASHTO T 297 (ASTM D 4767) Consolidated-Undrained Triaxial Compression Test on Cohesive Soils
- AASHTO T 307 Resilient Modulus of Soils and Aggregates Materials
- ASTM D 6758 Stiffness of Soil and Soil-Aggregates by the Soil Stiffness Gauge

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AASHTO and ASTM Test Procedures

11. Specific Gravity, Absorption and Unit Weight of Aggregates:

- AASHTO T-84 (ASTM C 128) Specific Gravity and Absorption of Fine Aggregates
- AASHTO T-85 (ASTM C 127) Specific Gravity and Absorption of Coarse Aggregates
- AASHTO T-19 (ASTM C 29) Unit Weight and Voids in Aggregates
- ASTM D 7172 Relative Density (Specific Gravity) and Absorption of Fine Aggregates Using Infrared

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AASHTO and ASTM Test Procedures

12. Frictional Properties of Aggregates and Pavements:

- AASHTO T-242 (ASTM E 274) Frictional Properties of Paved Surfaces Using a Full-ScaleTire (skid trailers)
- AASHTO T-279 (ASTM D 3319) Accelerated Polishing of Aggregates Using the British Wheel
- AASHTO T-278 (ASTM E 303) Measuring Surface Frictional Properties Using the British Pendulum Tester (BPT)
- ASTM D 3042 Insoluble Residue in Carbonate Aggregates
- ASTM E 707 Skid Resistance of Paved Surfaces Using the NC State Variable-Speed Friction Tester
- ASTM E 660 Accelerated Polishing of Aggregates or Pavement Surfaces Using a SmallWheel Circular Polishing Machine

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AASHTO and ASTM Test Procedures

13. Measurements and Indices of Particle Shape and Texture:

- ASTM D 1252 (AASHTO T 304) Uncompacted Void Content of Fine Aggregates
- ASTM D 4791 Flat or Elongated Particles in Coarse Aggregates
- ASTM D 3398 Index of Aggregates Particle Shape and Texture
- ASTM D 5821 (AASHTO TP 61) Fractured Particles in Coarse Aggregates

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